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Analysis of Gravels from the Arctic Ocean Floor

The following material is based on a report by Walter Schwarzacker and Kenneth Hunkins, both of the Lamont Geological Observatory, Columbia University. The original, more-detailed report, prepared by Lamont for the Geophysics Research Directorate of the Air Force Cambridge Research Laboratories, was published as AFCRC-TN-60-258, Dredged Gravels from the Central Arctic Ocean, *October 1960. An associated report on seismic studies of the Arctic Basin appeared in* Bulletin No. 46, *April 1961.*

Among the investigations conducted at IGY Drifting Station Alpha during its period of occupation, was a program of collecting dredge and core samples from the floor of the Arctic Ocean along portions of the drift-path of the ice floe on which the station was built. The dredge samples taken consisted mostly of glacial gravels, predominantly of sedimentary composition, which are believed to have been ice-rafted from shore areas to the central portions of the Arctic Basin.

A series of nine bottom-trawl operations obtained the dredge samples when the station was in the region 84°–85°N, 138°–152°W. (See Figure 1.) Also obtained in these studies were 14 bottom cores and about 200 bottom photographs. The high percentage of gravels and sands on the Arctic Ocean floor is the most remarkable sedimentation feature observed in this region. The relative density of such gravels is impressively seen in the bottom photographs. (*Bulletin No. 46* provides background information on Drifting Station Alpha and its program of IGY geophysical studies, and refers to earlier *Bulletins* also containing reports on the station, its programs, and related Arctic Basin studies.)

Sampling and Analysis Techniques

Most of the gravel samples were taken with a small bottom trawl consisting of a net held in place by a steel frame. The mouth opening was 10 × 100 cm, and the net had a mesh of 0.5 mm. The trawl was towed by the drifting ice floe for periods of one to four hours, and the actual distance traveled by the trawl on the bottom ranged from about 300 to 1600 meters. One sample was also obtained with a bucket dredge and another with a grab sampler. In addition, one rock was brought up accidentally when it became wedged in a sprocket wheel

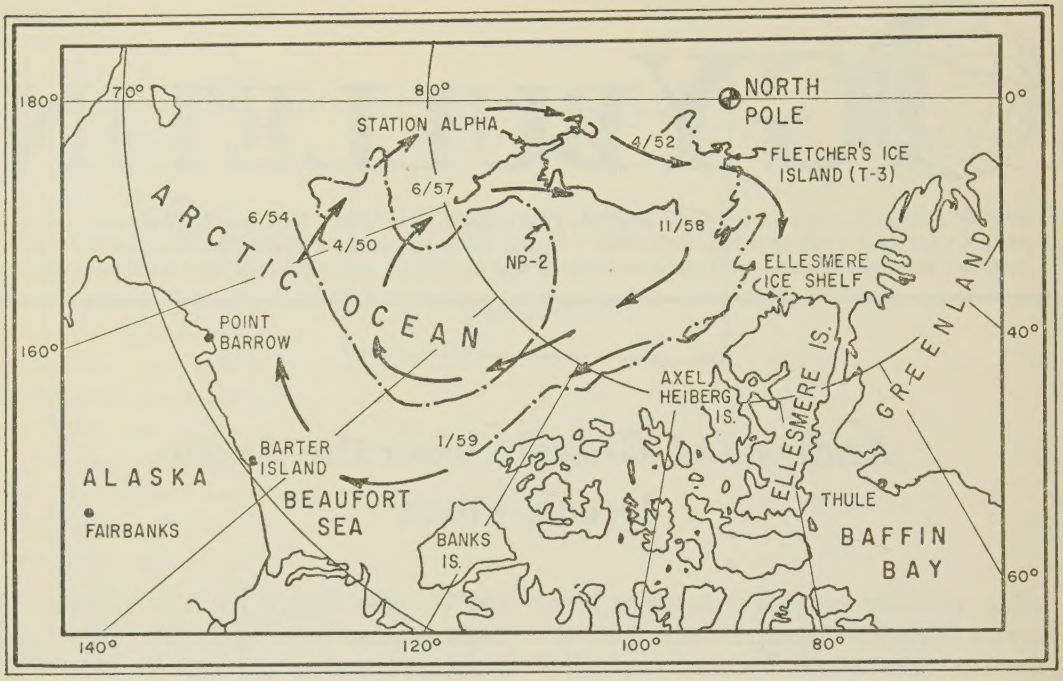

Fig. 1. *Drift Paths of US-IGY Station Alpha, Fletcher's Ice Island, and USSR Station NP-2 in the North Canadian Basin. Arrows indicate circulation pattern in this portion of the Arctic Ocean. Solid line shows path of Station Alpha, broken lines those of Fletcher's Ice Island and NP-2.*

used as a weight during another study. Obviously, material collected by these methods represents only the topmost layers of the bottom sediment.

The samples consisted generally of one to four liters of brown mud mixed with various amounts of sand and gravel. Since the mesh of the dredge net was 0.5 mm, the samples represent the bottom sediment only for particle sizes greater than this. The smaller fractions, best examined in the core samples, are partly normal marine sediment and partly glacial marine sediment.

All dredge samples were washed and sieved, and the fraction consisting of grain sizes larger than 3 mm was examined in detail under the binocular microscope. Sandstone, shale, and metamorphic and igneous rock types were separated by inspection; limestones [$CaCO_3$] and dolomites [$MgCa(CO_3)_2$], were differentiated by chemical staining. Gravels larger than 20 mm in size were thin-sectioned and examined under the polarizing microscope.

The composition of the various sieve fractions seems to vary with some regularity. Especially notable are the increase of shale and sandstone in the fraction less than 4 mm in grain size and the maximum occurrence of dolomite in the fraction with grain sizes between 4 and 10 mm. It appears that grain size is determined to some extent by rock type.

Description of Rock Samples

The percentages of the various rock types (in terms of weight) making up the portion of each dredge sample consisting of material greater than 3 mm in grain size, are given in Table 1. Gravels with diameters greater than 20 mm are described in some detail below. The aim of this descriptive analysis of the samples is to attempt to obtain a more positive identification of their source areas.

Limestone: The limestones in Samples 1 and 2 are all of the same type. Hand specimens are light gray to light blue in color. Under the microscope, these limestones are found to be true calcilutites (made up of calcareous rock flour) with some patches consisting of mosaics of coarser, recrystallized calcite. Some shell fragments and crinoid ossicles constitute a small proportion of the rock. Specks of limonite produced by alteration of pyrite can be seen in some of the thin-sections examined under the microscope.

A light gray to yellow limestone pebble found in Sample 3 contains a large number of shell fragments in a calcilutite matrix. Among the fragments are brachiopods (tentatively identified as chonetids and productids), gastropods, crinoid ossicles, and some bryozoans. The limestone is probably Permo-Carboniferous in age (i.e., formed 205–255 million years ago).

A yellow-gray limestone unlike any in the other samples was found in Sample 6. This limestone, a calcilutite with some small recrystallized areas, contains many poorly preserved fossils—probably brachiopod shells and foraminiferal tests—and a few pyrite crystals. The presence within it of small limestone mud pebbles suggests that this limestone was formed under shallow-water conditions.

Dolomite: The dolomite found in all of the dredge samples appears to be of the same type. It is white or white-brown in color and is invariably recrystallized into a fine- to medium-grained dolomite marble with crystals arranged in a mosaic pattern. In two specimens, a preferred orientation of the crystal axes was noted, suggesting that the rock has undergone some tectonic deformation. Fine-grained, clastic quartz grains are interspersed in places within the dolomite or form small lenses of sandstone. Fossil remains are rare and those found are not identifiable.

It is likely that the dolomites found in these samples dredged from the bottom of the Arctic Ocean are derived from an extensive series of sedimentary rocks originally deposited under shallow-water conditions, and that the dolomite layers may

Table 1. Weight Percentages of the Various Rock Types in Station Alpha Dredge Samples.

No.	Location	Depth (Meters)	Fraction >3 mm	Fraction >20 mm	Rock Types* (%)			
					Ls	Dol	Ss & Sh	Ig & Met
1	83° 59′ N 151° 44′ W	2590	135 gm	None	15	26	50	9
2	84° 09′ N 150° 23′ W	2490	1029 gm	253 gm	32	36	27	5
3	84° 16′ N 149° 11′ W	1658	30 gm	None	13	29	43	15
4	84° 22′ N 148° 51′ W	1776	23 gm	None	21	22	44	13
5	84° 27′ N 148° 28′ W	1700	3307 gm	2698 gm	11	33	54	2
6	84° 33′ N 146° 24′ W	2201	93 gm	None	14	42	36	8
7	84° 30′ N 145° 00′ W	2294	156 gm	None	16	45	35	4
8	84° 31′ N 143° 30′ W	2118	None	103 gm	0	100	0	0
9	85° 01′ N 138° 00′ W	1840–1910	8739 gm	8692 gm	8	5	3	84

* Ls = limestone; Dol = dolomite; Ss = sandstone; Sh = shale; Ig = igneous; Met = metamorphic

once have been interbedded with layers of sandstone.

Sandstone and Shale: A single sandstone pebble found in Sample 1 is dark gray in color and consists of angular quartz grains, .01–.05 mm in diameter, in a fine-grained cementing matrix of mica and chlorite. The quartz grains show signs of having been subjected to strain at some time in the past.

One large sandstone specimen, in which subangular .02–.1 mm quartz grains are cemented together by a matrix of calcareous material, was present in Sample 3. The specimen is highly fossiliferous, and a number of brachiopods and bryozoans, indicating a Permo-Carboniferous age (more likely Permian) for the specimen, have been identified. Crinoid ossicles and gastropod fossils also occur.

Another sandstone specimen, a dark-green, graywacke-type rock with wisps of black shale parallel to the bedding planes, contains very-well-rounded quartz grains many of which show well-developed strain lamellae. The mica matrix of this sample also exhibits "flow structure" deformation, and low-grade metamorphism is thus likely. A similar sandstone pebble shows a greater degree of metamorphism, with interpenetrating grain boundaries, and other sandstone specimens appear relatively unaltered. A pink specimen found in Sample 6 consists of close-fitting, well-rounded quartz grains cemented with calcite.

One specimen of conglomerate, consisting of well-rounded, dark-gray to black chert pebbles and a few quartzite pebbles in a matrix of quartz sandstone and chert, was found. A loose piece of chert in Sample 5 contains a large amount of calcareous organic detritus and a few grains of quartz and of glauconite. (Glauconite, a green hydrous potassium-iron silicate closely related to mica, commonly occurs in sediments of marine origin.)

Igneous and Metamorphic Rocks: Sample 9 consists mostly of a single large diabase cobble weighing 7300 gms. Under the microscope, it is seen to be made up of a large mass of lath-shaped crystals of plagioclase feldspar, with an intergrowth of large plates of pyroxene. Some magnetite, amphibole, and grains of quartz are also present. A metamorphic pebble, composed of chloritoid schist, was found in Sample 1.

Core Samples: In addition to those found in abundance in the materials dredged from the ocean floor, pebbles were also obtained from various depths beneath the floor in core samples. The pebbles found in the cores are generally small—the largest was 17 mm in diameter—and in many respects they resemble those in the dredge samples.

One core contained a pebble of basic igneous rock at a depth of 115 cm, and a piece of metamorphic rock—a sericite schist—was found at a depth of 46 cm in another. A light-gray limestone pebble with some shell fragments (possibly brachiopods) was discovered 46 cm down in a core; a dolomite pebble similar to those in the dredge samples occurred at 64 cm in another core; and a fine-grained sandstone pebble was found at 69 cm in still another.

Comparisons with Soviet Samples

Comparison of the Station Alpha data with data from Soviet drifting station NP-2 (1954–1955) shows that the composition of the bottom gravels in this portion of the Arctic Ocean is fairly uniform. The Russian dredge samples, though taken at a distance of 200 to 600 miles from those of Station Alpha, are quite similar in relative composition to the Station Alpha gravels. (See Figure 2 for a graphical comparison.) However, no agreement is seen between the dredged gravels obtained by stations Alpha and NP-2 and rocks found on the surface of T-3, or Fletcher's Ice Island, on which US-IGY Drifting Station Bravo was situated. (Fletcher's Ice Island is a large ice island thought to have broken away from the Ellesmere Ice Shelf; see *Bulletin Nos. 24* and *27*.)

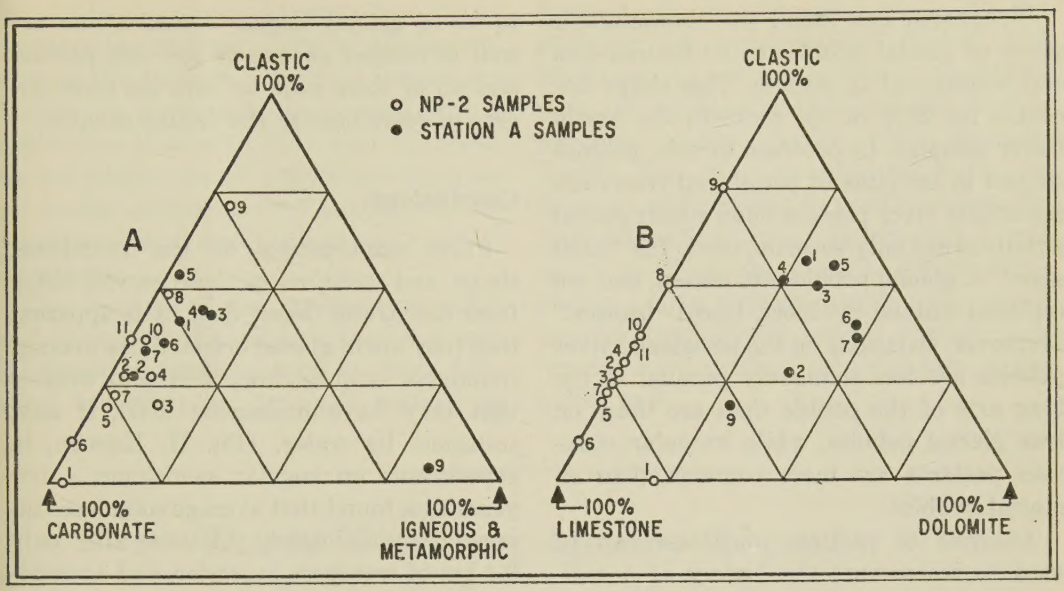

Fig. 2. *Comparison of Percentages of Various Rock Types, by Weight, in Dredge Samples from Drifting Station Alpha and from NP-2. Diagram A compares carbonate-igneous-clastic composition, showing a close similarity between Station Alpha and NP-2 samples; diagram B compares limestone-dolomite-clastic composition, for which agreement between samples collected by the two stations is not as good. While the proportion of carbonates to clastics is about the same in both sets of samples, Station Alpha carbonates have a relatively greater amount of dolomite and NP-2 carbonates are almost entirely limestones.*

Manganese Coatings and Worm Tubes

All specimens of the dredged rocks larger than 20 mm, and a large number of the smaller pebbles, are partly covered with a thin (probably less than 0.001 mm), black manganese coating. The coating is restricted to portions of the pebbles that were exposed to the sea water; the portions buried in mud are not coated.

Examination of 18 pebbles oriented approximately in their original positions, as indicated by the boundaries of the manganese coatings, showed that the average ratio of depth of the buried portions to height of the exposed portions is about 1:3. This ratio does not correlate with rock size. Similar manganese coatings occur on the pebbles found in core samples, indicating that they too were at one time exposed to sea water.

The manganese-coated portions of many of the dredged rocks are encrusted with worm tubes, but no living specimens were found in any of the worm tubes and many of the tubes are themselves coated with manganese.

Surface Texture and Roundness of Pebbles

Nearly half of the 27 rocks larger than 20 mm in diameter distinctly show striations resulting from glacial action. C. K. Wentworth in 1936 found a similar proportion of striated rocks in moraine deposits left by glaciers. As expected, limestones in the dredge samples usually have the best preserved striations. Striations on dolomites are relatively short, coarse, and poorly preserved. Some of the limestone pebbles have highly polished surfaces. Under the microscope, the polish was seen to be abrasive and to contain many minute scratches in the direction of the large striae.

Wentworth has found the characteristic shape of glacial pebbles to be flatiron-like and pentagonal in outline. This shape accounts for 26% of the rocks in the Arctic Basin samples. In contrast to this, pebbles shaped in ice jams of periglacial rivers are essentially river pebbles upon which glacial striations are only superimposed. The "snub scars" of glacial pebbles are absent, and are replaced instead by short, broad "bruises." Moreover, striations on the periglacial river pebbles are less commonly parallel to the long axis of the pebble than are those on true glacial pebbles, while irregular striation patterns are more common than on glacial pebbles.

Analysis of particle roundness can be used to reconstruct the history of a sediment. A large number of factors influence rounding, including two unknown quantities of particular importance—the environment in which rounding took place and the length of time the sediment was exposed to that environment. Several different roundness coefficients have been developed by various investigators.

From each dredge sample, 25 limestone and 25 dolomite pebbles ranging in size from 2 to 10 mm were chosen for roundness measurements. In most water-transported sediments, a relationship exists between the size of the pebbles and their roundness, and thus only pebbles of a uniform size group are strictly comparable. Whether a similar relation exists for glacial material is not known. A comparison of three size ranges of dolomite pebbles from dredge Sample 2 showed an apparent decrease of roundness with increase in grain size, but this increase is not statistically significant. Also, a comparison between dolomite and limestone pebbles showed no significant difference in roundness. In general, the roundness of the Station Alpha material agrees well with the roundness of glacial tills, as found previously by various authors.

Although the cores yielded only five pebbles for examination, these too appear to be of glacial origin. Glacial striae are well developed on one of the core pebbles and all of them seem to have the same degree of roundness as the dredge samples.

Conclusions

From examination of the roundness, shape, and striations of these gravels taken from the Arctic Ocean floor, it is apparent that they are of glacial origin. Since average roundness is quite low, it is also evident that they have undergone little, if any, transport by water. (Ph. H. Kuenen, in experiments on angular sandstones a few years ago, found that average roundness increased approximately 2.4 times after only 0.4 km of transport by water, and approximately 5 times after 3 km of transport. Observations by Wentworth, in 1922, showed that a travel distance of only 0.35 miles was sufficient to remove striae from hard limestones and greenstones.)

Thus, it appears that these Arctic Basin gravels have been ice-rafted from a coast on which active glaciers reached the shore. It is probable that the material was transported in icebergs that had calved directly from the glaciers. Also, at least part of the material was frozen into the bottom of either grounded icebergs or sea ice. A. Clarke, Jr., has studied the molluscan shells from these same dredge samples and concludes that, since they are shallow-water species, many of the shells have been transported from their source areas to the deep-water locations at which they were found, undoubtedly after having been picked up by grounded ice in shallow water near the shore.

Oceanic circulation in this area (see *Bulletin No. 24*) and the extent of Pleistocene glaciation considerably limit the possible source areas for these gravels. The circulation pattern in the North Canadian Basin makes it likely that the material was obtained from the northern coast of Greenland, the Canadian Arctic Archipelago, or

the northern coast of Alaska. (See Figure 1.) Since the northern coast of Alaska and most of the northern Canadian islands are believed to have been unglaciated during Pleistocene time (the "Ice Age" of about the last million years), possible source areas are further limited to Axel Heiberg Island, Ellesmere Island, and the northern coast of Greenland.

Two features of the gravel composition tend to support this choice of source areas: (1) One sandstone specimen has been definitely identified by its fossil content as Permo-Carboniferous, and strata of the same age are found on Axel Heiberg and Ellesmere islands and on northern Greenland. (2) All Station Alpha dredge samples contained a characteristic white dolomite marble that may be identical with the dolomite of Cambrian to pre-Cambrian age (430–510 million years or greater) found earlier in these same areas. Future comparison of the bottom gravels with actual samples from Arctic coastal regions may provide more positive identification of the source area.

World Warning Agency Report

October 1 - December 31, 1960

This report, one of a series issued periodically during and following the IGY and IGC-59 periods, is based on (i) the final quarterly report for 1960 by the World Warning Agency (AGIWARN), originally established as part of the IGY World Days Program, and (ii) compilations of Solar-Geophysical Data *for the above period, issued by the Central Radio Propagation Laboratory of the National Bureau of Standards in November and December 1960 and January 1961.*

AGIWARN activities are supervised by J. M. Weldon. Another report in this issue of the Bulletin *outlines the World Days plan for 1961–62 and provides additional information about the International World Days Service and related activities.* Bulletin No. 43 *contains a report on major flares, geomagnetic disturbances, world-wide Geophysical Alerts, and Special World Intervals for the third quarter of 1960.*

Of 12 geomagnetic disturbances recorded during the final quarter of 1960, Advance Alerts were issued for 7 and world-wide Geophysical Alerts were issued for 11. Storms for which Advance Alerts were not issued either were too minor to meet Alert criteria or began only a few hours before 1600 UT and therefore could not be announced effectively by a world-wide Alert.

No world-wide Alert was issued for the very minor October 4 disturbance which ended several hours before the 1600 UT issue time. Two world-wide Alerts issued in connection with the intense solar activity associated with the great geomagnetic storm that began November 12 were unusual in that both announced a cosmic-ray increase. Only one cosmic-ray increase Alert has ever been issued before by AGIWARN. In addition, the world-wide Alert issued on November 15 referred to a sudden-commencement-type resurgence of the November 12 magnetic storm. (A more complete discussion of these events is given below.)

Seven of the magnetic storms recorded during the quarter began gradually. None of these was readily predictable on the basis of the tendency for magnetic storms to recur at 27-day intervals, although some appeared to fit vague patterns of recurrence. It may be a year or more before the period of the solar cycle is reached when the 27-

day-recurrence pattern becomes distinct enough to be used effectively in forecasting actual disturbances. Of special interest is the storm that began gradually on October 5. It was unusually severe and lasted longer than any storm in the past two years. Research groups in Regional Warning Centers as well as in CRPL have given this storm special emphasis in their studies.

Of five sudden-commencement-type storms recorded during the quarter, three were preceded by observable solar events and were predicted by AGIWARN. The other two, which occurred on October 24 and November 24, were not expected. Certain statistical sun-earth relationships might have been applied toward successful prediction of the former. The latter, except for its sudden beginning, might be considered as a recurrence of a storm that first occurred 27 days earlier.

List of Major Events

The following is a list of major solar flares, geomagnetic disturbances, and worldwide Geophysical Alerts and SWI issued by AGIWARN during the last quarter of 1960 (October 1–December 31):

Sep	30	13xx*	Magnetic storm begins
Oct	1	1600	Alert issued (MAGSTORM)**
	2	19xx	Magnetic storm ends
	4	14xx	Magnetic storm begins
	5	10xx	Magnetic storm ends
		19xx	Magnetic storm begins
	6	1600	Alert issued (MAGSTORM); auroras probable SWI starts†
	8	2359	SWI finishes
	14	2033	Class 3 flare
	24	1450	Severe magnetic storm begins
	25	1600	Alert issued (MAGSTORM)
	29	1026	Class 3 flare; G-SWF††
Nov	1	09xx	Severe magnetic storm ends
	3	22xx	Magnetic storm begins
	4	1600	Alert issued (MAGSTORM)
	5	09xx	Magnetic storm ends
		1250	Class 3 flare
	6	1752	Class 3 flare; S-SWF
	10	1009	Class 3+ flare; S-SWF
	12	1315	Class 3+ flare; S-SWF
		1350	Very severe magnetic storm begins (A-index of 275, highest ever recorded by AGIWARN, reached on November 13)
		1600	Alert issued (MAGSTORM) SWI starts
	13	1600	Alert issued (COSRAY INCREASE)
	14	2359	SWI finishes
	15	1600	Alert issued (COSRAY INCREASE; MAGSTORM) SWI starts
	17	21xx	Very severe magnetic storm ends
		2126	Class 3 flare
		2359	SWI finishes
	20	1955	Class 3 flare; S-SWF
	21	04xx	Magnetic storm begins
		1600	Alert issued (MAGSTORM)
	22	13xx	Magnetic storm ends
	24	2053	Magnetic storm begins
	25	1600	Alert issued (MAGSTORM)
	26	15xx	Magnetic storm ends
	30	1910	Severe magnetic storm begins
Dec	1	1600	Alert issued (MAGSTORM)
	3	00xx	Severe magnetic storm ends
	5	1825	Class 3+ flare; S-SWF
	7	1804	Magnetic storm begins
	8	1600	Alert issued (MAGSTORM)
		16xx	Magnetic storm ends
	15	07xx	Magnetic storm begins
	16	1600	Alert issued (MAGSTORM)
		16xx	Magnetic storm ends
	27	03xx	Magnetic storm begins
		1600	Alert issued (MAGSTORM)
	28	21xx	Magnetic storm ends

Notes:

* "xx" indicates gradual beginning or ending of a disturbance, following the hour indicated, such that the precise moment could not be determined.

** No ending times for Alerts are issued; this is left to the discretion of the individual observatories. Capitalized acronyms indicate the kind of Alert issued: MAGSTORM = magnetic storm; COSRAY INCREASE = cosmic-ray increase.

† SWI's start at the time the associated Alert is issued (1600 UT) and finish at the end of the day indicated (2359 UT).

†† G-SWF = gradual ionospheric disturbance with irregular fading in either drop-out or recovery, or in both; S-SWF = sudden short-wave fadeout and gradual recovery.

Intense Solar-Terrestrial Activity During the Period November 5–17

Because of the extremely interesting solar activity and corresponding terrestrial effects that occurred between November 5 and November 17, this period is discussed below in some detail (with limitations imposed, however, by the preliminary nature of the solar and geophysical data available at this time).

On November 5, a medium-sized calcium plage rotated onto the sun's east limb at about 20° North Latitude. By November 6, a giant complex sunspot group was observed accompanying the plage. (The plage had been visible during the previous solar rotation and had been relatively inactive throughout its transit until nearing the west limb, when, during the last two days of observation, a large spot-group had developed.)

By November 8, the 20-cm radio-noise flux had increased greatly, and 107-mc radio-noise outbursts classified as major and major+ had been recorded, with the large sunspot region as the likely source. (A major burst is an outburst of solar radio noise of large amplitude and longer than average duration; the designation major+ refers to a major burst followed by another, comparable rise in noise flux.)

On November 10 at 1009 UT, Wendelstein Observatory (Germany) observed an importance-3 flare of very long duration in the growing region. This flare was accompanied by several major and major+ solar-noise outbursts on various frequencies. Huancayo Observatory (Peru) reported observing an importance-2 flare in the same location about four hours later. Intermittent observations at McMath-Hulbert Observatory (Michigan) indicated that Huancayo may have witnessed the latter stages of the 1009 UT flare. Severe short-wave radio fadeouts were experienced at several stations associated in time with the flare event. However, the observatory at College, Alaska, reported no discernible polar-cap radio absorption.

On November 11, reports of other severe short-wave fadeouts were received; the most severe, occurring near 0300 UT that day, was accompanied by further major solar-noise bursts and by very large disturbances recorded by radio spectrographs in Sydney, Australia. With the above information available, the North Atlantic Radio Warning Service issued a Special

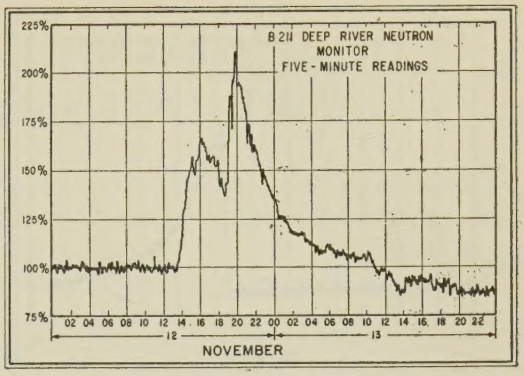

Fig. 3. *Cosmic-Ray Increase on November 12–13, 1960, as Shown by Neutron-Monitor Record from the Canadian Station at Deep River, Ontario. A peak increase of over 100% was reached at about 2000 UT on November 12, followed by a drop to values approximately 10–15% below the mean after about 1300 UT on the 13th. This decrease continued until the 15th, when another large increase occurred (see Fig. 4). Record submitted to CRPL by H. Carmichael and J. Steljes, Atomic Energy of Canada, Ltd.*

Disturbance Warning (at 2038 UT November 11) predicting that a radio and geomagnetic disturbance would begin on November 12.

At 1325 UT November 12, McMath-Hulbert observed an importance-3+ flare in the same solar region, then just east of the sun's central meridian. The flare was also observed by the Sacramento Peak (New Mexico) and Nederhorstdenberg (Netherlands) observatories. AGIWARN distributed the flare information via special telegram and accompanying an Advance Solar Flare Alert. At 1350 a magnetic storm began suddenly and at 1600 UT a world-wide Magnetic Storm Alert containing the decision to begin an SWI was issued by AGIWARN.

Later, on the 12th, many reports of short-wave fadeouts and solar-noise outbursts were received, all in time association with the great flare. Also received was a report from the University of Chicago of a strong cosmic-ray increase beginning about 1345 UT (see Fig. 3), and College reported the

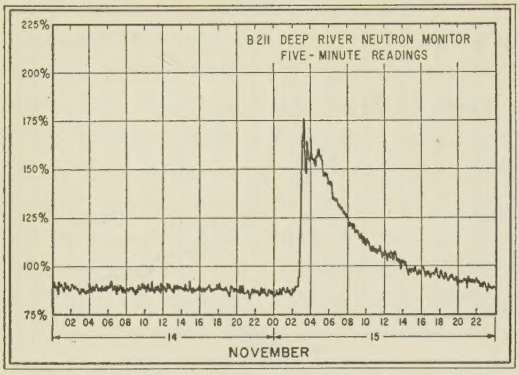

Fig. 4. *Cosmic-Ray Increase on November 15, 1960, as Shown by Deep River Neutron-Monitor Record. A peak increase of about 75% was reached at approximately 0300 UT, followed by a decline to about 10–15% below the mean toward the end of the day. Record submitted to CRPL by H. Carmichael and J. Steljes.*

beginning of strong polar-cap absorption at 1700 UT. Both the polar-cap absorption and the cosmic-ray increase were still in progress at 2100 UT. The IZMIRAN (USSR) and Kakioka (Japan) observatories both reported the magnetic storm via Advance Magnetic Storm Alerts. The storm reached great severity in the early hours of the 13th, and by late that day an A-index of 275, the highest on record at AGIWARN, had been reached. The SWI begun by AGIWARN at 1600 UT November 12 was continued via a World Wide Alert at 1600 UT November 13, along with notification of the cosmic-ray increase.

The next major flare activity in the region was observed November 14. Mitaka Observatory (Japan) reported a 2+ flare at 0246 UT, and observation of three class-2 flares, at 0015 UT, 1836 UT, and 2118 UT, were made at Hawaii, Sacramento Peak, and Burbank, California, respectively. The 2+ flare was accompanied by major radio-noise outbursts on several frequencies. The SWI continued through the 14th, while the magnetic storm continued but decreased in intensity.

At 0207 UT November 15, Mitaka observed another 3+ flare in the same solar region, then about three days east of the sun's central meridian. Many major radio-noise outbursts, over a wide range of frequencies, were recorded in time association with the event. The University of Chicago reported a 50% increase in cosmic radiation between 0200 UT and 0300 UT (see Fig. 4), and riometers at College showed another intense polar-cap-absorption event by 1000 UT. A Cosmic Ray Increase Advance Alert was issued by AGIWARN. Magnetographs at AGIWARN, which had become relatively quiet between 0300 and 1200 UT on November 15, showed a marked sudden-commencement-type resurgence at 1305 UT. The world-wide Alert issued at 1600 UT referred to the Cosmic Ray increase at 0200 UT and to the marked increase in magnetic activity at 1305 UT, and began another Special World Interval that was continued through November 17.

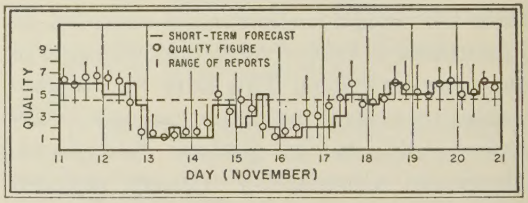

Fig. 5. *Radio-Quality Disturbances, November 12–19, 1960, in the North Atlantic Region. The chart compares actual quality figures with the short-term forecast, using a scale ranging from 1 to 9 (1 = useless, for medium-powered radio, 3 = poor, 5 = fair, 7 = good, and 9 = excellent). Prepared by CRPL, NBS, at Boulder, Colorado.*

No further reports of major flare activity were received and the solar region involved, still containing a large plage and a sunspot group, was rotated beyond the sun's west limb on November 19. The magnetic disturbance ended on November 17, late in the day. During this series of events, short-wave radio-propagation conditions became disturbed during the last half of November 12 (see Fig. 5), remained severely disturbed through November 16, and recovered to near normal by November 19.

Plan for Geophysical Alerts and Special World Intervals during 1961-1962

The following material is based on an information circular issued by the World Warning Agency (AGIWARN) for distribution to all geophysical stations and observatories of nations participating in the continuing international program of World Days and Communications, begun during the IGY and now known as the International World Days Service (IWDS). AGIWARN was set up during the IGY by the Special Committee for the IGY (CSAGI) of the International Council of Scientific Unions (ICSU).

The circular describing the new plan for Geophysical Alerts and Special World Intervals (SWI) was issued by James M. Weldon, Head, AGIWARN, under the general supervision of J. V. Lincoln in association with A. H. Shapley, IWDS Spokesman. Questions concerning the plan should be addressed to the IWDS World Warning Agency at the address below. (The World Days programs for the IGY and IGC-1959 are described in IGY Bulletin Nos. 5 *and* 23, *respectively;* Bulletin No. 42 *contains a report on the International Geophysical Calendar for 1961, and other* Bulletins *review program results on a quarterly basis.)*

The plan described in this report for Geophysical Alerts and Special World Intervals during the period 1961–62 supersedes previous plans established for the IGY, IGC-59, and 1960. The new plan will remain in effect at least through 1962, although some minor modifications may be needed as a result of changes in the level of solar activity.

Under the 1961–62 plan, an *Alert* is issued as soon as possible after an exceptional solar or geophysical event has occurred or has started, and serves to aid the observing programs at geophysical stations. Advance Alerts (ADALERT's) are issued by Regional Warning Centers (RWC's), as described below, and are distributed immediately by telegram or radio to local geophysical stations and to the other RWC's. Geophysical Alerts (GEOALERT's) are for world-wide distribution and are issued by the World Warning Agency. There are four different kinds of Alerts—Solar Flare, Magnetic Storm, Cosmic Ray, and Aurora, with specific criteria for each.

Special World Intervals (SWI's) are declared only by AGIWARN, and the pertinent information is included in the GEOALERT message. Many geophysical stations carry out special observing programs during SWI's. (Note: Words shown entirely in capital letters—i.e., ADALERT, GEOALERT, etc.—are abbreviations for use in telegraphic messages; sample messages are shown below.)

It is assumed that geophysical stations interested in receiving Alerts have communications channels by telegraph or radio broadcast with one of the four RWC's or with Associate RWC's. Alternatively, geophysical stations may have access to an outlet of the meteorological telecommunications network coordinated by the World Meteorological Organization (WMO). However, only the GEOALERT (i.e., international) messages are carried on this network. Geophysical stations that do not have suitable communications channels should make arrangements with the appropriate RWC or with AGIWARN.

Advance Alerts (ADALERTS)

Any Regional Warning Center may issue an "Advance Alert" as soon as the outstanding solar or geophysical phenomenon is recognized and the RWC is satisfied that

it meets the stated criteria. The Advance Alert message should be distributed as promptly as is practical within the RWC region, and should also be sent promptly to each of the other RWC's for their information and action in case the event was missed by stations in their regions. These prompt Advance Alert messages serve both to aid the observing programs at individual geophysical stations and to provide advice to the World Warning Agency on the declaration of world-wide Geophysical Alerts.

Criteria: The RWC's use the following criteria for the four kinds of Advance Alerts:

Solar Flare (SOFLARE) Alert—issued when a solar flare of median importance (2+), or greater, has been reported; there will be only one alert issued per flare, and only one a day at most.

Magnetic Storm (MAGSTORM) Alert—issued whenever a significant magnetic storm (K figure of 5 or greater at a middle-latitude station) has begun.

Cosmic Ray (COSRAY) Alert—issued whenever a very outstanding change in cosmic-ray flux (either an increase or a decrease) has been observed.

Aurora Alert—issued whenever a magnetic storm in middle latitudes has reached a K-figure of at least intensity 7 (AURORA PROBABLE) or whenever selected auroral stations report the presence of outstanding auroras (AURORA OBSERVED).

Message Forms: The texts for Advance Alert messages are in the standard forms shown in the following samples, and include identification of the stations reporting the event, nature of the event, and time of the event:

(a) ADALERT KOKUBUNJI SOFLARE 280010Z (Solar flare event of importance 2+ or greater observed by Kokubunji at 0010 UT on 28th day of month.)

(b) ADALERT NIZMIR MAGSTORM 291900Z (NIZMIR recorded beginning of significant magnetic storm—K-figure of 5 or greater—at 1900 UT on 29th day of month.)

(c) ADALERT ZUGSPITZE COSRAY DECREASE 061130Z (Nominal time of unusual cosmic-ray-flux decrease recorded at Zugspitze was 1130 UT on the 6th day of month.)

(d) ADALERT CORNELL AURORA OBSERVED 070230Z (Outstanding aurora observed by Cornell University, USA, at 0230 UT on the 7th day of month.)

(e) ADALERT AGIWARN AURORA PROBABLE MAGSTORM 070230Z (Beginning of significant magnetic storm—K-figure of 7 or greater—recorded at AGIWARN at 0230 UT on 7th day of month; auroral displays should be expected.)

GEOALERTS, Including SWI

Only the World Warning Agency issues declarations of world-wide Geophysical Alerts and of Special World Intervals. These declarations are made at 1600 UT on any day when the course of solar and geophysical activity makes them appropriate. Declaration of a world-wide Alert is made after consideration of Advance Alerts issued by one or more RWC's, which also provide advice concerning inclusion of SWI's in the declarations. All messages begin with the words "GEOALERT NOxxx," where "NO" is the message abbreviation for "number" and xxx is the serial number of the GEOALERT message issued.

GEOALERTS: World-wide Geophysical Alerts may be declared in one or more of the following categories: Magnetic Storm, Cosmic Ray Increase, and Aurora. The criteria are the same as those given for Advance Alerts and the Geophysical Alert message is in a standard text specifying the nature and time of the event. Samples of possible messages are as follows:

(a) GEOALERT NO135 MAGSTORM 051000Z (The 135th world-wide Geophysical Alert issued; a significant magnetic storm—K-figure of 5 or greater—started at 1000 UT on 5th day of month.)

(b) GEOALERT NO015 AURORA PROBABLE MAGSTORM 100716Z (The 15th world-wide Geophysical Alert issued; a magnetic storm with K-figure of 7 or greater started at 0716 UT on 10th day of month; auroral displays should be expected.)

(c) GEOALERT NO010 COSRAY INCREASE 061825Z (The 10th world-wide Geophysical Alert issued; nominal time of an unusual cosmic-ray-flux increase was 1825 UT on 6th day of month.)

(d) GEOALERT NO022 AURORA 120940Z (The 22nd world-wide Geophysical Alert issued;

outstanding aurora observed at 0940 UT on 12th day of month; stations to west should expect to observe aurora.)

Special World Intervals: A GEOALERT message is issued to start an SWI, messages are issued every day thereafter to continue it, and another is issued to finish the SWI. An SWI usually lasts one or two days. The SWI may be based on a prediction that important geomagnetic and associated activity will start in the next few hours; in this case, the words "PREDICTED SWI" will be used in the message until the activity actually starts. For an SWI declared when important geomagnetic and associated activity is already in progress, the term "SWI" will be used alone.

An SWI is considered to start when the "START SWI" or "START PREDICTED SWI" message is received by a geophysical station. The SWI is considered over by 2359 UT of the day the "FINISH SWI" or "FINISH PREDICTED SWI" message is issued. The following are samples of possible messages (explanations of messages are similar to those above, but include SWI information; additional comments are made where needed):

(a) GEOALERT NO031 MAGSTORM 051000Z START SWI 051600Z
(b) GEOALERT NO032 CONTINUE SWI 061600Z (Special World Interval continues for another day.)
(c) GEOALERT NO033 FINISH SWI 072359Z
(d) GEOALERT NO050 START PREDICTED SWI 101600Z (Stations should conduct the SWI program appropriate to their geophysical disciplines; a major geomagnetic storm is predicted.)
(e) GEOALERT NO051 MAGSTORM 102314Z CONTINUE SWI 111600Z (Significant magnetic storm started at 2314 UT on the 10th day of month; thus, predicted SWI started by GEOALERT NO050 was successful and the SWI declared on 10th day of month at 1600 UT is to continue on the 11th.)
(f) GEOALERT NO052 FINISH SWI 122359Z
(g) GEOALERT NO051 CONTINUE PREDICTED SWI 111600Z (Major geomagnetic storm still predicted.)
(h) GEOALERT NO051 FINISH PREDICTED SWI 111600Z (There is no longer a high probability that a major geomagnetic storm will begin; therefore, finish SWI programs upon receipt of message.)

Communications Channels for GEOALERTS

Meteorological Telecommunications Network: GEOALERT messages are delivered at 1600 UT to the WMO meteorological telecommunications network at Washington, D. C. The message is then distributed throughout the world in accordance with plans developed by WMO. Geophysical stations may make arrangements with nearby meteorological stations for receiving the messages. On days when no GEOALERT message is issued, the meteorological network will carry the message IGC KWWA XX/XXXXZ NEGATIVE.

Distribution by Regional Warning Centers: AGIWARN also sends GEOALERT messages at 1600 UT by telegram to each RWC. Further distribution within each region then takes place according to plans made by the RWC for that region.

Radio Broadcasts: The general content of GEOALERT messages is indicated by a symbol broadcast repeatedly in Morse code on National Bureau of Standards radio stations WWV and WWVH twice each hour. Beginning at 1604 UT, the symbol is first broadcast at 4 and 34 minutes past each hour on WWV, and beginning at 1714 it is also broadcast at 14 and 44 minutes past each hour on WWVH. Similar broadcasts are made in the various RWC regions. The symbols, *sent in very slow and deliberate code,* are as follows:

AGI	EEEEE	
.– ––. ..	. . . . .	state of "No Worldwide Alert"
AGI	AAAA	
.– ––. ..	.– .– .– .–	state of "Worldwide Alert"
AGI	(3 extra-long dashes)	
.– ––. ..	—— —— ——	SWI in progress

Warning Centers

The addresses of AGIWARN and of the various RWC's are given below to enable geophysical stations to establish suitable communications channels:

IWDS World Warning Agency

AGIWARN
Box 178, Ft. Belvoir, Virginia, USA
Washington, D. C., SOuth 5-6411 or SOuth 5-8436
Attn: James M. Weldon

Regional Warning Centers

Western Europe:

Radio Receiving Station NERA
Nederhorst den Berg
Netherlands
Attn: L. D. De Feiter

Jours Mondiaux
196, rue de Paris
Bagneux (Seine), France
Attn: A. Delouf

Fernmeldtechnisches Zentralamt (FTZ)
Rheinstrasse 110, Darmstadt
Federal German Republic
Attn: G. Richter

Eurasia:

Institute of Terrestrial Magnetism,
Ionosphere and Radio Propagation
(IZMIRAN)
Moscow, USSR
Attn: L. N. Liakhova

Western Pacific:

Radio Research Laboratories
Kokubunji, P.O., Koganei-shi, Tokyo, Japan
Attn: T. Takiguchi

Western Hemisphere:

IWDS World Warning Agency (AGIWARN)
(Details same as above.)

Associate Regional Warning Centers

Australasia:

Ionosphere Prediction Service
5 Hickson Road, Millers Point
Sydney, N.S.W. Australia
Attn: F. E. Cook

Alaska:

North Pacific Radio Warning Service
National Bureau of Standards
Box 1119, Anchorage, Alaska
Attn: L. W. Honea

Sweden:

The Royal Board of Swedish Telecommunications
Brunkebergstorg, 2
Stockholm 16, Sweden
Attn: Sven Gejer

Coordination and Administration

The 1961–62 World Days plan is coordinated by IWDS of ICSU and administered by the International Scientific Radio Union (URSI). The members of the IWDS Steering Committee are A. H. Shapley, IWDS spokesman (URSI); M. Nicolet (International Union of Geodesy and Geophysics); J. F. Denisse (International Astronomical Union); and R. Coutrez, Secretary (URSI, 7 Place Emile Danco, Brussels). The plan was worked out jointly with the URSI Central Committee on Ursigrams (CCU), which coordinates the telegraphic collection, interchange, and distribution of summaries of current solar and geophysical data. Members of the CCU, and the regions they represent, are N. V. Pushkov (USSR), Eurasia; R. L. Smith-Rose (UK), Western Europe; H. Uyeda (Japan), Western Pacific; A. H. Shapley (USA), Western Hemisphere; and R. Coutrez, Secretary (URSI).

Arrangements for the distribution of GEOALERT messages were worked out in cooperation with the WMO. The re-introduction of "PREDICTED SWI" into the plan for 1961–1962, which had been omitted in the 1960 plan, was decided on at a joint IWDS-CCU meeting in London, September 12, 1960.

IGY Bibliographic Notes

The following bibliographic references relating to IGY and IGC-1959 programs and findings were selected from a bibliography under preparation in the Science and Technology Division of the Library of Congress.

J. K. Bannon: Stratospheric Temperatures Over the Antarctic. *Quarterly Journal Royal Meteorological Society.* Vol. 84, no. 362. Oct. 1958. Pp. 434–436, Diagr., refs.

V. F. Burkhanov, B. L. Dzardzeyevsky, Kh. P. Pogosian, and G. M. Tauber, eds.: Climate of Antarctica. *Proceedings of Complex Antarctic Expedition of USSR Academy of Sciences.* Moscow, 1959. 288 p. Diagr., illus., maps, refs.

A. P. Crary: Antarctica. *Transactions of the American Geophysical Union.* Vol. 40, no. 4. Dec. 1959. Pp. 331–339. Refs.

Maurice Ewing and William L. Donn: On Pleistocene Surface Temperatures of the North Atlantic and Arctic Oceans. *Science.* Vol. 131, no. 3390. Jan. 8, 1960. Pp. 99.

R. Gonfiantini and E. Picciotto: Oxygen Isotope Variations in Antarctic Snow Samples. *Nature.* Vol. 184, no. 4698. Nov. 14, 1959. Pp. 1557–1558. Diagr., refs.

R. Jastrow: Outer Atmospheres of the Earth and Planets. *Journal of Geophysical Research.* Vol. 64, no. 11. Nov. 1959. Pp. 1789–1798. Diagr., refs.

W. B. Kamb: Ice Petrofabric Observations from Blue Glacier Washington, in Relation to Theory and Experiment. *Journal of Geophysical Research.* Vol. 64, no. 11. Nov. 1959. Pp. 1891–1909. Diagr., illus., refs.

T. N. Krishnamurti: A Vertical Cross Section Through the Polar-Night Jet Stream. *Journal of Geophysical Research.* Vol. 64, no. 11. Nov. 1959. Pp. 1835–1844. Maps, refs.

Gerald P. Kuiper: The Moon. *Journal of Geophysical Research.* Vol. 64, no. 11. Nov. 1959. Pp. 1713–1719. Refs.

H. Leinbach and G. C. Reid: Ionization of the Upper Atmosphere by Low-Energy Charged Particles from a Solar Flare. *Physical Review Letters.* Vol. 2, no. 2. Jan. 15, 1959. Pp. 61–63. Illus.

L. B. Lockhart, Jr., R. A. Baus, R. L. Patterson, Jr. and A. W. Saunders, Jr.: Radiochemical Analyses of Air-Filter Samples Collected During 1958. *NRL Report No. 5390.* Oct. 23, 1959. 14 p. Figs.

J. MacDowall: Geomagnetic Activity at Halley Bay on Disturbed Days. *Nature.* Vol. 184, no. 4698. Nov. 14, 1959. Pp. 1557–1558. Diagr.

A. Maxwell, A. R. Thompson, and G. Garmire: The Association of Solar Radio Bursts with Auroral Streams. *Planetary and Space Science.* Vol. 1, no. 4. Sept. 1959. Pp. 325–332. Diagr., refs.

T. Nagata and Y. Shimisu: Natural Remanent Magnetization of Pre-Cambrian Gneiss of Ongul Islands in the Antarctic. *Nature.* Vol. 184, no. 4697. Nov. 7, 1959. Pp. 1472–1473. Diagr., refs.

H. Odishaw: International Geophysics Committee. *Transactions of the American Geophysical Union.* Vol. 40, no. 4. Dec. 1959. Pp. 347–350.

C. B. Officer, J. I. Ewing, J. F. Hennion, D. G. Harkrider, and D. E. Miller: Geophysical Investigations in the Eastern Caribbean: Summary of 1955 and 1956 Cruises. *Physics and Chemistry of the Earth.* Pergamon Press. (London and New York) 1958. Pp. 17–109. Diagr., illus., maps, refs.

E. Parker: Extension of the Solar Corona into Interplanetary Space. *Journal of Geophysical Research.* Vol. 64, no. 11. Nov. 1959. Pp. 1675–1678.

J. Paton: The Polar Aurora. *Quarterly Journal Royal Meteorological Society.* Vol. 82, no. 354. Oct. 1956. Pp. 396–408. Diagr., illus., refs.

M. H. Rees: Absolute Photometry of the Aurora—I and II. *Journal of Atmospheric and Terrestrial Physics.* Vol. 14. 1959. Pp. 325–337, 338–344. Diagr., refs.

A. Rosen, P. J. Coleman, Jr., and C. P. Sonnett: Ionizing Radiation Detected by Pioneer II. *Planetary and Space Science.* Vol. 1, no. 4. Sept. 1959. Pp. 343–346. Diagr., refs.

A. H. Shapley: Preliminary Assessment of the IGY. *Proceedings of the National Electronics Conference.* Oct. 13–15, 1958. 5 p.

G. Sutton and J. Oliver: Seismographs of High Magnification at Long Periods. *Annales de Géophysique.* Vol. 15, no. 4. Oct.-Dec. 1959. Pp. 423–433. Diagr., refs.

W. L. Tressler: *Oceanographic and Hydrographic Observations at Wilkes IGY Station, Antarctica.* U. S. Navy Hydrographic Office. Washington. Oct. 1959. 25 p.

USSR Academy of Sciences: *Glaciological Researches During the IGY.* No. 1. Moscow. 1959. 103 p. Diagr., illus., refs.

USSR National Committee for the IGY: *IGY Bibliographic Index of Literature in the Russian Language for 1958.* Moscow. 1959. 63 p.

E. Upton, A. Bailie, and P. Musen: Lunar and Solar Perturbations on Satellite Orbits. *Science.* Vol. 130, no. 3390. Dec. 18, 1959. Pp. 1710–1711. Diagr., refs.

E. H. Vestine and W. L. Sibley: Lines of Force of the Geomagnetic Field in Space. *Planetary and Space Science.* Vol. 1, no. 4. Sept. 1959. Pp. 285–290. Diagr., refs.

F. L. Whipple: Solid Particles in the Solar System. *Journal of Geophysical Research.* Vol. 64, no. 11. Nov. 1959. Pp. 1653–1654. Refs.

J. R. Winckler: *Non-Relativistic Protons From Solar Flares.* American Association for the Advancement of Science. Dec. 28, 1959. 27 p. Diagr., illus., refs.

SCIENCE IN SPACE

A volume entitled *Science in Space* has been prepared by members of the Space Science Board of the National Academy of Sciences-National Research Council. The book, consisting of 20 chapters organized into several major categories of space research, was edited by Lloyd V. Berkner (Chairman) and Hugh Odishaw (Executive Director) of the Board.

Science in Space was published by McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York 36, New York. The 439-page volume contains 106 illustrations and tables. It is priced at seven dollars. The chapters and their authors are as follows:

Part 1—A General Review

1. Dimensions and Problems, L. V. Berkner and Hugh Odishaw
2. Results of Experiments in Space, Bruno Rossi and Robert Jastrow

Part 2—Gravity

3. The Nature of Gravitation, R. H. Dicke

Part 3—The Earth

4. Knowledge of the Earth from Space, Harrison Brown
5. Some Aspects of Geodesy, George P. Woollard
6. Meteorology, Harry Wexler
7. Rocket Research and the Upper Atmosphere, W. W. Kellogg
8. Satellites and the Upper Atmosphere, A. H. Shapley and O. G. Villard, Jr.

Part 4—The Moon and the Planets

9. The Moon, H. C. Urey
10. The Planets, H. C. Urey

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11. Physics of Fields and Energetic Particles in Space, J. A. Simpson
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15. The Geomagnetically Trapped Corpuscular Radiation, James A. Van Allen
16. On Particles and Fields Pertinent to Auroral Theory, Joseph W. Chamberlain

Part 6—The Stars

17. The Sun, Leo Goldberg and E. R. Dyer, Jr.
18. Galactic and Extragalactic Astronomy, Leo Goldberg and E. R. Dyer, Jr.

Part 7—The Life Sciences

19. The Biological Sciences and Space Research, Joshua Lederberg and H. Keffer Hartline
20. Exobiology: Experimental Approaches to Life beyond the Earth, Joshua Lederberg

Part 8—Appendix

The scientific knowledge and concepts on which *Science in Space* is based are derived from the work of a broad spectrum of American and foreign scientists. Detlev W. Bronk, President of the National Academy of Sciences, sat with the Board during critical discussions, contributing advice and guidance. All members of the Space Science Board and of its committees have contributed to preparation of the volume through discussion, criticism, and editorial comment. In addition, many scientists outside the formal organization of the Board have given freely of their time and assistance.

BULLETIN SUBSCRIPTIONS

***IGY Bulletin* subscriptions are now available for the period July 1961–June 1962 (*Bulletin Nos. 49–60*). Subscriptions for the preceding 12-month interval terminate with *Bulletin No. 48*, June 1961. Prices for renewals, or for new subscriptions, for the July 1961–June 1962 period are as follows: teachers' and students' single subscriptions, $1.50; teachers' and students' multiple subscriptions (5 or more mailed to a single address), $1.00; other subscriptions, $2.00.**

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